MECHATRONICS BOOK SERIES

CONTROL AND INTELLIGENT SYSTEMS

Momoh Jimoh E. Salami
Abiodun Musa Aibinu
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Chapter 13
Backstepping Control of an Autonomous Quadrotor

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13.1 Introduction

A quadrotor vehicle is a flying robot with four rotors that provide lift and control. It is referred to as a small agile flying vehicle, which has four propellers driven by four rotors located at the front, rear, left, and right ends of a cross shaped frame. This chapter presents design and control of an autonomous quadrotor. A quadrotor is a highly nonlinear, multivariable, strongly coupled system with 6 DOF that have only 4 actuators. It exhibits a number of important physical effects such as aerodynamic effects, inertial counter torques, gravity effect, gyroscopic effects and friction. Thus, it is difficult to design a real-time controller for the quadrotor.

The quadrotor used as the testbed in this research is a modified version of Gaui 330X Quad Flyer. The airframe, the motors and the propellers are the original model. However, it is equipped with additional sensors and electric circuitry. The complete craft includes the airframe, four driver systems; ESC-motor-propeller assemblies, a microcontroller, inertial measurement unit (IMU) and ultrasonic sensors, wireless communication (Xbee module) and power supplies. The configuration is illustrated in Figure 1.

This chapter presents control design for the autonomous quadrotor. The control strategy adopted includes feedback linearization coupled with Proportional-Derivative (PD) controller for the translational subsystem and backstepping based Proportional-Integral-Derivative (PID) controller for the rotational subsystem. It is developed in MATLAB/Simulink platform and is validated via real-time implementation.

This chapter is organized as follows. Section 2 presents the mathematical model of the quadrotor. Section 3 presents the control design. Section 4 evaluates the control performance of the closed loop system. Finally, Section 5 concludes the chapter.

13.2 Mathematical Model of a Quadrotor

The dynamic equations for quadrotor are derived based on Newton-Euler formalism, which is more comprehensive. The modelling of quadrotor differs from the one used for fixed wing vehicle. For quadrotor, the final rotation of the body to earth frame transformation along the thrust direction is carried out. The first set of differential equation that describes the acceleration of the quadrotor can be written as:

$$\Lambda_{tr} = [\ddot{x}, \ddot{y}, \ddot{z}]^T, \qquad \Lambda_{tr} = \frac{u_1}{m}\begin{bmatrix} -(c\phi s\theta s\psi - s\phi c\psi) \\ -(c\phi s\theta s\psi - s\phi c\psi) \\ g-(c\phi c\theta) \end{bmatrix}, \tag{13.1}$$